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SIXTEENTH ANNUAL REPORT OF THE COMMITTEE ON ATOMIC WEIGHTS. DETERMINATIONS PUBLISHED DURING 1908.

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During the calendar year 1908 a moderate number of investigations upon atomic weights have been published, but the total output is not large. The data are summarized in the following pages, together with a few items dated 1907, which were not accessible until after the publication of the report for that year.

Chlorine.—Noyes and Weber¹ effected the complete synthesis of hydrochloric acid, weighing the hydrogen in palladium and the chlorine in the form of potassium chloroplatinate. The hydrochloric acid produced by passing the hydrogen over the heated chloroplatinate was also collected and weighed. In one series of experiments the acid was directly collected by absorption in water; in the second series, previous to absorption, it was condensed to the solid form. For details, the original paper must be consulted; only the following final results, with all corrections applied, can be given here first on the basis of $H = 1$.

SERIES I.

Weight H.	Weight Cl.	Weight HCl.	At. wt. Cl.	Mol. wt. HCl.
0.25394	8.93293	9.18695	35.177	36.178
0.28004	9.85590	10.13259	35.195	36.183
0.51821	18.23468	18.75359	35.188	36.189
0.67631	23.79587	24.47123	35.186	36.185
0.58225	20.48158	.....	35.177	.....
0.47989	16.88423	17.36310	35.184	36.182
0.64132	22.55816	23.20054	35.175	36.176
			Mean.....	35.183
				36.181

¹ THIS JOURNAL, 30, 13.

SERIES II.

Weight H.	Weight Cl.	Weight HCl.	At. wt. Cl.	Mol. wt. HCl.
0.81608	28.71691	29.53107	35.188	36.187
0.83194	29.28055	30.11207	35.195	36.195
0.39074	13.74926	14.14078	35.187	36.188
0.75560	26.58427	27.33926	35.183	36.182
0.77518	27.26746	28.04110	35.177	36.175
			Mean.....	35.186
			Mean of all.....	35.184
				36.185
				36.183

With H = 1.00762, Cl = 35.452. With H = 1.00787 (Noyes), Cl = 35.461. The authors adopt 35.457 as the most probable value.

Edgar's¹ syntheses of hydrochloric acid were differently conducted. The hydrogen was weighed in palladium, but the chlorine was taken directly in the liquid form, having been prepared by the electrolysis of fused silver chloride. The chlorine was burned at the end of a quartz tip in an atmosphere of hydrogen, and the hydrochloric acid was also weighed. In three experiments the acid was condensed to solid and so weighed; in two others it was weighed after absorption in water. The corrected data are as follows; with H = 1.

Weight H.	Weight Cl.	Weight HCl.	At. wt. Cl.	Mol. wt. HCl.
2.1452	75.5026	77.6469	35.196	36.196
2.0387	71.7504	73.7880	35.194	36.194
1.7762	62.5004	.....	35.188	.....
1.9935	70.1638	72.1565	35.196	36.196
1.6469	57.9671	.....	35.198	.....
2.1016	73.9662	.....	35.195	.....
1.7254	60.7162	62.4401	35.190	36.189
2.0885	73.4991	75.5859	35.192	36.191
			Mean.....	35.194
				36.193

With H = 1.00762, Cl = 35.462 and 35.461, in close agreement with the former work of Dixon and Edgar. This is higher by 0.01 than the determinations of Noyes and Weber.

There is also a preliminary note by Gray² on the density and volumetric composition of HCl. Twenty determinations gave for the weight of a normal liter of the gas the value 1.63885 grams. It was then analyzed volumetrically by passage over heated aluminum, and measurement of the volume of hydrogen set free. The ratio thus found is $H_2 \div HCl = 1.00790$. From these data, combined with Morley's figures for the density and atomic weight of hydrogen, Cl = 35.453. The details of the investigations are yet to be published.

¹ *Phil. Trans.*, **209**, A, 1.

² *Proc. Chem. Soc.*, **24**, 215. Additional work on Cl by Guye and Fluss and by Oechsner de Coninck was received too late for use in this year's report.

Nitrogen.—Guye and Pintza¹ have determined the density of the gaseous mixture $N_2 + 3H_2$ produced by the decomposition of $2NH_3$. The corrected weight of a normal liter is given as 0.37989 gram. Combining this with the densities of nitrogen and hydrogen they find that the volume ratio $N:3H = 1:3.00172$. Hence, if $H = 1.0076$, $N = 14.014$. The authors attach little importance to this determination, but regard it as having corroborative value.

Sulphur.—Baumé and Perrot² have determined with great care the density of hydrogen sulphide. From 18 determinations they find the weight of a normal liter of the gas to be 1.5392 grams. Reducing this by means of the critical constants the atomic weight of sulphur becomes $S = 32.070$, in good agreement with the chemical determinations by Richards and Jones.

Lead, Zinc, and Cadmium.—In a thesis published in 1907, but only recently received, Luigi Meaglia³ gives approximate determinations of the atomic weights of lead, zinc, and cadmium. His method consisted in precipitating metallic silver or gold from suitable solutions by known weights of the three metals under consideration. For lead, two sets of values are given, representing two preparations of the metal. With these, silver was thrown down from silver nitrate solutions, and weighed. With $Ag = 107.93$ the following values for Pb were obtained.

Series I.	Series II.
206.872	206.866
206.907	206.897
206.903	206.927
206.909	206.933
206.930	206.935
206.903	.....
206.929	.....

By means of zinc, silver was thrown down from a sulphate solution, and gold from a solution of sodium chloraurate. With $Ag = 107.93$ and $Au = 197.2$ the subjoined values for Zn were found.

Silver series.	Gold series.
65.58	65.509
65.45	65.424
65.50	65.440
65.41	65.470

With cadmium, two similar series of determinations were made, giving for Cd the following values:

¹ *Compt. rend.*, **147**, 925. The work of Guye and his colleagues upon the atomic weight of N has recently been published in collected form. See *Mém. Soc. Phys.*, etc., de Genève, v. 35, fascicule 4. See also Leduc, *Compt. rend.*, **146**, 399, on the atomic weights of N, O, and C.

² *J. chim. phys.*, **6**, 610. In an earlier paper, *J. chim. phys.*, **6**, 1, Baumé gives density and critical determinations for SO_2 , $(CH_3)_2O$, and CH_3Cl .

³ *Thesis*, University of Grenoble, 1907.

Silver series.	Gold series.
112.37	112.41
112.56	112.45
112.45	112.65
112.38	112.47
.....	112.48
.....	112.40
.....	112.42
.....	112.41

These determinations, as the author admits, are only crude approximations. Still, they have some corroborative significance.

The atomic weight of cadmium has also been determined by Blum,¹ who converted the oxide into the sulphide by heating in a current of hydrogen sulphide. His figures, with vacuum weights, are as follows:

Weight CdO.	Weight CdS.	Atomic weight.
1.80552	2.03108	112.62
0.66349	0.74617	112.88
1.82460	2.05256	112.54
1.88424	2.11974	112.50
3.59206	4.04081	112.55
4.38093	4.92695	112.86

These results are discordant and entitled to very little consideration. Blum also tested several other methods of determination, and found them to be unsatisfactory. When silver was precipitated by cadmium from a nitrate solution, silver nitrite was formed, and the precipitate contained some cadmium.

Bismuth.—Three papers upon the atomic weight of bismuth have been published by Gutbier,² in collaboration with Birckenbach, Mehler, and Janssen. The data had previously appeared in Inaugural Dissertations by the three collaborators, and are given in my reports for 1906 and 1907.

Tellurium.—In a paper upon the homogeneity of tellurium Lenher³ has given one analysis and one synthesis of TeO_2 , as follows:

0.85635 TeO_2 gave 0.6845 Te. Hence $\text{Te} = 127.52$.

0.1694 Te gave 0.2119 TeO_2 . Hence $\text{Te} = 127.55$.

These figures represent different fractions of the material investigated.

Rhodium.—Hüttlinger,⁴ in order to determine the atomic weight of rhodium, reduced chloropentamminrhodium chloride by heating in hydrogen. His figures, which are preliminary in character, are as follows:

¹ *Thesis*, University of Pennsylvania, 1908.

² *J. prakt. Chem.*, **77**, 457; **78**, 409 and 421.

³ *This JOURNAL*, **30**, 741. For a criticism of Marckwald's work on tellurium, see Baker, *Chem. News*, **97**, 209.

⁴ Inaugural Dissertation, Erlangen, 1907.

Weight chloride.	Weight Rh.	Atomic weight.
1.60574	0.56124	102.906
1.67310	0.58492	102.943
1.30182	0.45507	102.925

Mean, 102.925

This value is identical with that previously found by Seubert and Kobbe.

Palladium.—Atomic weight redetermined by Haas,¹ who reduced palladosammine bromide by heating in hydrogen. The results obtained, with vacuum weights, were as follows:

Weight bromide.	Weight Pd.	Atomic weight.
2.06470	0.73274	106.73
1.73455	0.61563	106.75
2.64773	0.93978	106.76
1.29106	0.45821	106.74
2.26758	0.80490	106.77
1.90770	0.67704	106.74
1.77729	0.63082	106.76

Mean, 106.75

The calculations were made with Br = 79.953, N = 14.037, and H = 1.008. Recalculated with Br = 79.92, N = 14.01, and H = 1.008, Pd = 106.69.

These figures are in close agreement with those found by Amberg, Krell, and Woernle. Much lower values were obtained by Kemmerer,² who reduced palladosammine chloride and cyanide by means of hydrogen. With the chloride, using different samples of material, two series of determinations were made, all weights being reduced to a vacuum.

Weight chloride.	Weight Pd.	Atomic weight.
0.89187	0.44885	106.40
0.77931	0.39218	106.38
0.66980	0.33711	106.41
1.08373	0.54541	106.40
0.96048	0.48338	106.40

Mean, 106.399

Weight chloride.	Weight Pd.	Atomic weight.
0.95615	0.48129	106.43
0.94087	0.47356	106.42
0.90106	0.45353	106.42
1.16994	0.58908	106.50

Mean, 106.442

¹ Inaugural Dissertation, Erlangen, 1908.

² THIS JOURNAL, 30, 1701.

Weight cyanide.	Weight Pd.	Atomic weight.
0.85860	0.47463	106.41
1.19378	0.66002	106.45
1.41818	0.78408	106.45
1.05254	0.58206	106.51
1.39510	0.77153	106.51
1.66196	0.91881	106.42

Mean, 106.458

The mean of the 15 determinations is Pd = 106.434, when Cl = 35.473, N = 14.01, and H = 1.008. Recalculation with Cl = 35.46 would lower this value slightly.

Uranium.—In two brief notes Oechsner de Coninck¹ has given determinations of the molecular weight of uranous oxide, UO₂. First, by calcination of UO₂Br₂ to UO₂ he obtained values ranging from 271.19 to 274.09. Second, by reducing UO₂Cl₂ in hydrogen he found UO₂ = 270.3, 270.1, and 270.4. Figures of this character are evidently not entitled to serious consideration.

Columbium.—The atomic weight of columbium has been determined by Balke and Smith² upon exceptionally pure material. The chloride, CbCl₅, was decomposed by water, with the aid of a little nitric acid, and the oxide so produced was finally ignited and weighed. The results, with vacuum weights, and with Cl = 35.45, are as follows:

Weight CbCl ₅ .	Weight Cb ₂ O ₅ .	Atomic weight.
9.56379	4.71539	93.49
5.42242	2.65730	93.42
5.15992	2.54364	93.44
9.64854	4.75641	93.44
7.24572	3.57222	93.47
8.00559	3.94746	93.51
9.60763	4.73852	93.58
9.19732	4.53638	93.58

Mean, 93.50

This value should supplant all the older determinations. With Cl = 35.46, Cb = 93.54.

Europium.—Jantsch³ has redetermined the atomic weight of europium, by calcination of the octohydrated sulphite, using very pure material furnished by Urbain. The data are subjoined:

Weight sulphate.	Weight oxide.	Atomic weight.
1.3501	0.6455	152.032
1.5054	0.7197	152.009
1.5213	0.7274	152.054
1.2881	0.6159	152.056

Mean, 152.038

¹ *Bull. Acad. Roy. Belg., Classe des Sciences*, 1907, 1041, and 1908 (2), 163.

² *THIS JOURNAL*, 30, 1644.

³ *Compt. rend.*, 146, 473.

Calculated with $H = 1.008$ and $S = 32.06$.

Erbium.—Hofmann and Burger,¹ having at their command the original erbium material studied by Nilson and Krüss, subjected it to further purification, and determined the atomic weight of the “neo-erbium” so obtained. By conversion of the oxide into the sulphate they secured the subjoined data:

Weight oxide.	Weight sulphate.	Atomic weight.
0.9048	1.4724	167.43
0.4666	0.7594	167.37
1.4181	2.3077	167.43
1.0789	1.7563	167.28

The highest value, 167.43, is preferred. Calculated with $S = 32.06$.

Ytterbium.—In my report for 1907, the work of Urbain upon ytterbium, by which it was decomposed into two elements, was mentioned. Urbain² has since given a series of atomic weight determinations, made upon fractionated preparations of the old ytterbium, and these ranged regularly from 170.66 to 174.02. The lower value is that of Urbain’s “neo-ytterbium;” the higher, that of his “lutecium.”

The same fractionation of ytterbium was also effected by Auer von Welsbach,³ who names the two new metals “cassiopeium” and “aldebaranium,” respectively. By conversion of the oxides into the sulphates he obtained the following atomic weight data:

ALDEBARANIUM.		
Weight oxide.	Weight sulphate.	Atomic weight.
0.4181	0.6730	172.98
0.5984	0.9634	172.88
0.6173	0.9939	172.85

Mean, 172.90

CASSIOPEIUM.		
Weight oxide.	Weight sulphate.	Atomic weight.
0.3716	0.5967	174.25
0.3086	0.4956	174.19
0.4026	0.6465	174.24

Mean, 174.23

The nomenclature of Urbain has clear priority over that of Welsbach, and is, therefore, to be preferred.

Radium.—Three determinations of the atomic weight of radium, upon

¹ *Ber.*, 41, 308.

² *Compt. rend.*, 146, 406. See also *Chem. Ztg.*, 32, 730, a discussion of priority over Welsbach.

³ *Monatsh. Chem.*, 29, 181.

very pure material, have been made by Thorpe,¹ who measured the ratio between RaCl_2 and 2AgCl . His data are as follows:

Weight RaCl_2 .	Weight AgCl .	Atomic weight.
0.0627	0.0604	226.8
0.0639	0.0618	225.7
0.0784	0.0753	227.7
		Mean, 226.7

Thorpe regards the atomic weight as now known to within a unit, and notes the agreement between his work and that of Mme. Curie. In order to check his method of determination, which involved the use of very small quantities of material, he made similar analyses of barium chloride and bromide, and obtained results in accord with those of Richards.

Krypton and Xenon.—Moore,² from the residues from 120 tons of liquid air, has isolated krypton and xenon in considerable quantities. The densities, referred to $\text{O} = 16$, and the corresponding atomic weights were as follows:

	Kr.	Xe.
Density.....	41.506	65.35
Atomic weight.....	83.012	130.70

In this connection it may be stated that Boltwood³ assigns to his "ionium" an atomic weight of about 230.

Miscellaneous Notes.

The subject of atomic weights in general has been treated by several authors. There is a useful summary by Richards⁴ of the Harvard work, and an essay by Lemoine⁵ on the unity of matter and the determination of atomic weights. Also a lecture by Jaquerod on modern researches upon atomic weights.⁶ Comstock⁷ has discussed the variability of these constants, and the evolution and devolution of the elements is considered by A. C. and A. E. Jessup.⁸ Bernoulli⁹ has attempted to compute the atomic weights on purely theoretical grounds, and so too has Stevens.¹⁰

On the calculation of atomic weights there are papers by Noyes,¹¹ Hin-

¹ *Proc. Roy. Soc., A*, **80**, 298; *Chem. News*, **97**, 229. H. Wilde has argued on theoretical grounds, that $\text{Ra} = 184$. See *Mem. Manchester Lit. Phil. Soc.*, No. 1, 1908, and *Phil. Mag.* [6], **15**, 280, and **16**, 825.

² *Proc. Chem. Soc.*, **24**, 273.

³ *Am. J. Sci.* [4], **25**, 380. A. T. Cameron, in *Science Progress*, **2**, 525, has given estimates of probable atomic weight for a number of radioactive emanations.

⁴ *J. Chim. Phys.*, **6**, 92.

⁵ *Revue des Questions Scientifiques, Bruxelles* [3], **14**, 182.

⁶ *Rev. Gén. des Sciences*, **19**, 443.

⁷ *Phil. Mag.* [6], **15**, 12.

⁸ *Ibid.*, p. 21.

⁹ *Phys. Z.*, **9**, 745.

¹⁰ *The Massing of Sphères*. London, 1908. Privately published.

¹¹ *THIS JOURNAL*, **30**, 4.

richs,¹ Dubreuil² and Leduc.³ The electrochemical equivalents of oxygen and hydrogen have been studied by Lehfelddt.⁴ On the silver voltameter and coulometer there are elaborate papers by Duschak and Hulett,⁵ and by Smith, Mather and Lowry.⁶ In the latter research the electrochemical equivalent of silver is fixed at 1.11827 mg. per coulomb.

In the International Table, published in this JOURNAL for March, there is a serious misprint. Zn should be 65.37 instead of 65.7.

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[CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.]

A REVISION OF THE ATOMIC WEIGHT OF ARSENIC.

PRELIMINARY PAPER—THE ANALYSIS OF SILVER ARSENATE.

BY GREGORY PAUL BAXTER AND FLETCHER BARKER COFFIN.

Received January 16, 1909.

Below is a summary of the previous work upon the atomic weight of arsenic,⁷ the results obtained by the several investigators having been recalculated with the use of the following atomic weights:⁸ O = 16.000; Ag = 107.880; Cl = 35.457; Br = 79.916; S = 32.07; K = 39.096; Na = 22.977; Cr = 52.01; Pb = 207.09.

1816 Thomson,	<i>Schweigger Jour.</i> , 17 , 421,	2As: As ₂ O ₅	76.35
1818 Berzelius,	<i>Pogg. Ann.</i> , 8 , 1,	2As ₂ O ₃ : 3SO ₂	75.03
1845 Pelouze,	<i>Compt. rend.</i> , 20 , 1047,	AsCl ₃ : 3Ag	74.93
1855 Kessler,	<i>Pogg. Ann.</i> , 95 , 204,	3As ₂ O ₃ : 2K ₂ Cr ₂ O ₇	74.95
		3As ₂ O ₃ : 2KClO ₃	75.23
1859 Dumas,	<i>Ann. Chim. Phys.</i> [3], 55 , 174,	AsCl ₃ : 3Ag	74.87
1859 Wallace,	<i>Phil. Mag.</i> (4), 18 , 279,	AsBr ₃ : 3Ag	74.20
1861 Kessler,	<i>Pogg. Ann.</i> , 113 , 140,	3As ₂ O ₃ : 2K ₂ Cr ₂ O ₇	75.01
1896 Hibbs,	Doctoral Thesis, Univ. of Penn.,	Na ₄ As ₂ O ₇ : 4NaCl	74.88
1902 Ebaugh,	<i>Jour. Amer. Chem. Soc.</i> , 24 , 489,	Ag ₃ AsO ₄ : 3AgCl	75.02
		Ag ₃ AsO ₄ : 3Ag	74.92
		Pb ₃ (AsO ₄) ₂ : 3PbCl ₂	75.06
		Pb ₃ (AsO ₄) ₂ : 3PbBr ₂	74.88

A glance at this rather discordant series of results shows the necessity for a redetermination of the atomic weight of arsenic. Even in the more recent investigations of Hibbs and Ebaugh there exists an extreme variation of nearly two-tenths of a unit in the averages of the five series.

¹ *Chem. Zent.*, 1908 (1), 1240; *Compt. rend.*, **146**, 971; **147**, 797, and **147**, 1302.

² *Compt. rend.*, **147**, 627, 856, and 1300.

³ *Ibid.*, **147**, 972.

⁴ *Phil. Mag.* [6], **15**, 614.

⁵ *Trans. Amer. Electrochem. Soc.*, **12**, 257.

⁶ *Phil. Trans.*, **207**, A, 545.

⁷ Clarke, A Recalculation of the Atomic Weights; Smith, Misc. Coll., Constants of Nature, Part V, p. 213 (1897). For an excellent critical discussion of previous work, by Brauner, see Abegg's *Handbuch der anorganischen Chemie*, **3** (2), 491 (1907).

⁸ Richards, *Jour. chim. phys.*, **6**, 130 (1908).